Nuclear and Wholesale Electricity Prices

Enclosed here are some of the results from the early review of the relationship between regional nuclear capacity fraction and regional wholesale power prices. Brad Eccles and Elizabeth King of NEI have put together a file that matched up electricity prices quoted to Megawatt daily since 1997 at particular hubs with the amount of nuclear capacity located at the most applicable NERC sub regions. The prices used in this analysis are daily on-peak prices measured in units of current Dollars per MWh, over the entire study period (1997-2002). The NEI analysts will extend this review to include the relationship of regional nuclear generation fraction (rather than capacity fraction), and regional wholesale energy prices.

1. Regional Electricity Prices and Nuclear Capacity Fractions

The relationship of regional nuclear capacity fraction and regional wholesale (on-peak) electricity prices are shown in Figure 1 below. The specific NERC sub-regions which include the fractional nuclear capacity levels indicated in this bar chart are listed in the Table 1 below. Tale 1 includes the regional nuclear capacity fractions, energy prices and price standard deviations (from the mean values) used in this analysis.

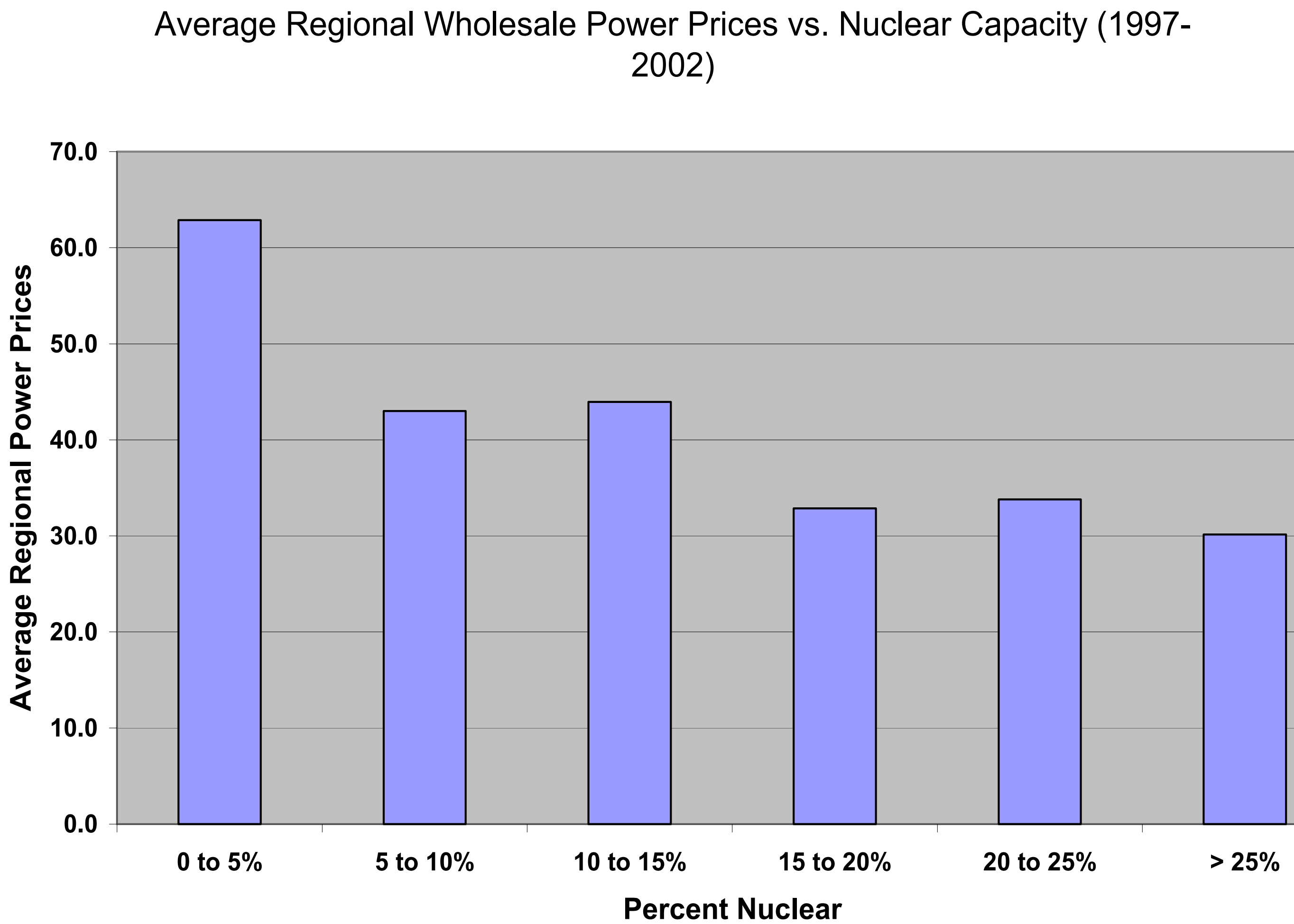

Figure 1

Nuclear Group	Plant NERC Sub-Region Name	Average of Prices	StdDev of Prices	Count of Prices
0	Northwest Power Area (NWPA) - U.S. Systems	62.9	125.5	3
0.05	CA/MX Power Area (CAMX) - U.S. Systems	79.3	88.2	2
	East Central Area Reliability Coord Agrmn (ECARSR)	34.6	80.9	3
	Electric Reliability Council of Texas (ERCOT)	33.2	20.5	3
	Florida Reliability Coordinating Council (FRCCSR)	40.9	15.5	1
	Northern Subregion (N)	32.7	48.9	2
0.1	Entergy (ENTR)	38.9	71.4	1
	Florida Reliability Coordinating Council (FRCCSR)	33.4	26.7	
	Mid-Continent Area Power Pool (MAPPSR)	29.9	48.6	2
	New York Power Pool (NYPP)	43.5	23.0	3
	Southern Subregion (STHRN)	38.1	59.3	3
	WECC AZ/NM/SNV Power Area (AZNMSNV)	82.2	92.4	2

0.15	Entergy (ENTR)	35.5	95.7	
	New England Power Pool (NEPOOL)	44.0	25.2	1
	New York Power Pool (NYPP)	25.6	8.7	1
	Tennessee Valley Authority (TVA)	32.7	15.0	1
	WECC AZ/NM/SNV Power Area (AZNMSNV)	29.2	11.8	2
0.2	MAIN Sub Region (MAINSR)	33.8	68.3	4
	New England Power Pool (NEPOOL)	27.9	4.3	
	PJM Interconnect PA-NJ-MD (PJM)	33.1	26.0	2
	Tennessee Valley Authority (TVA)	38.0	113.3	1
	Virginia/Carolinas Subregion (VACAR)	33.8	14.9	
0.25	MAIN Sub Region (MAINSR)	30.1	90.1	1

Table 1

Inspection of Figure 1 indicates that the average regional electricity prices, over the period, decline as the percent of installed nuclear capacity in the region increases. In other words, as the fraction of nuclear capacity installed in a region increases, regional on-peak electricity prices decline. It looks like nuclear holds down energy prices in a region on average. This is true for regional nuclear capacity fractions ranging from zero to 25 percents. The impact of installed nuclear capacity on regional wholesale electricity price reductions is estimated as seen in the regression analysis presented in Figure 2, with the statistical parameters summarized in Table 2.

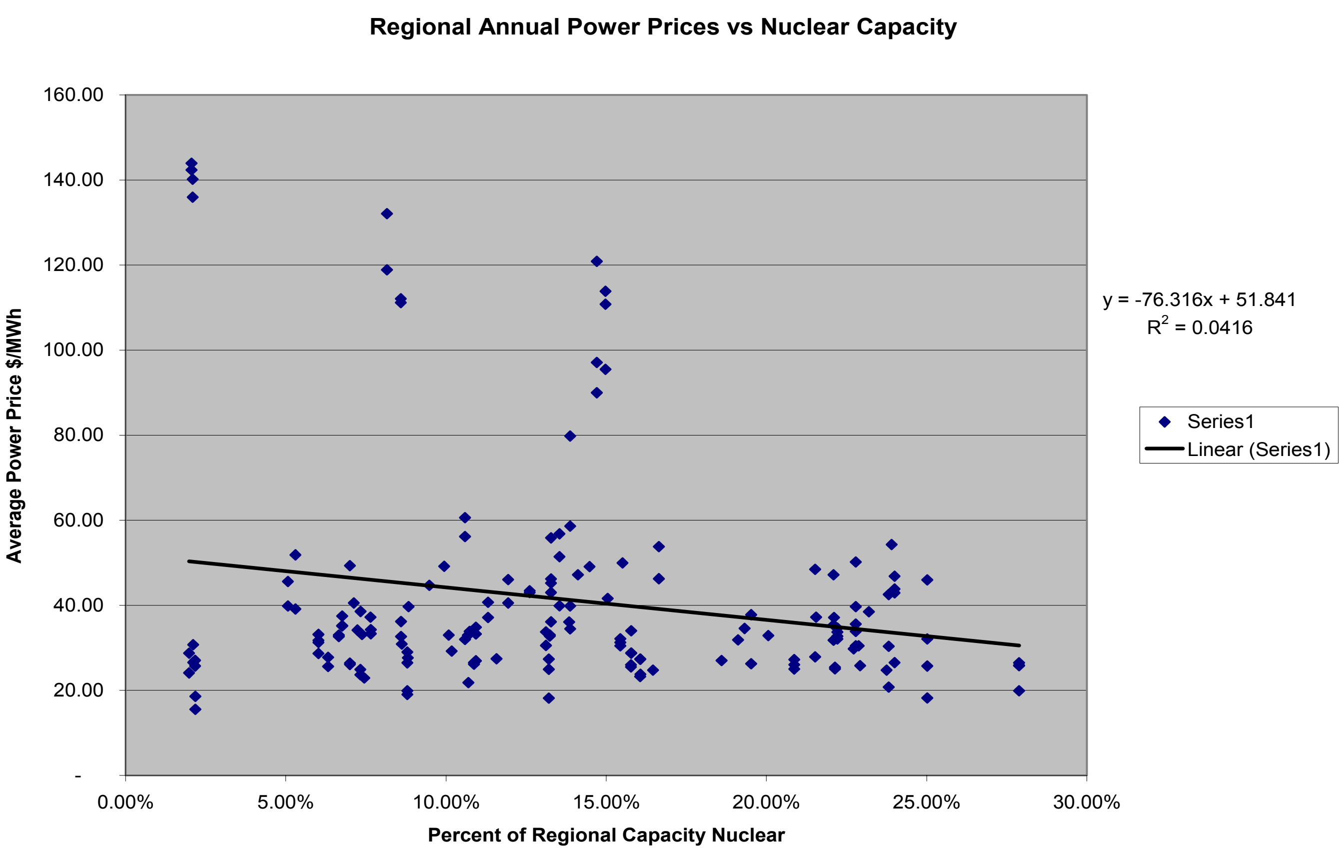

Figure 2

The results of the statistical analysis carried out by NEI are shown in the regression line of Figure 2 above. For every increase of 5% in the contribution of nuclear power to regional generation, regional wholesale power prices fall by $3.8/MWh. If we assume that national wholesale electricity prices average at 45.0 $/MWh, then a 5 percent increase in nuclear capacity across a wide range of regions will result in an 8.4 percent decline in average wholesale electricity prices.

The above results are statistically meaningful and significantly different from zero. It should however be mentioned that the downwards trend in prices as regional nuclear capacity increases is heavily influenced by the high observations from the California energy crisis of late 2001.

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.20
R Square	0.04
Adjusted R Square	0.04
Standard Error	25.27
Observations	169.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	4,625.68	4,625.68	7.24	0.01
Residual	167.00	106,629.93	638.50		
Total	168.00	111,255.61			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	51.84	4.36	11.90	0.00	43.24	60.44
Average of Nuclear Capacity	(76.32)	28.35	(2.69)	0.01	(132.29)	(20.34)

Table 2

2. EU Countries' Electricity Prices and Nuclear Generation

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A complementary analysis of the relationship between electricity prices to specific classes of residential and industrial customers, and nuclear fraction of total electricity generation in several European Union (EU) countries, was performed by Chaim Braun.

Electricity prices to various residential and industrial consumer classes in several EU countries, in 1999 (the last year for which prices are recorded), are reported by Eurostat – the statistical agency of the EU. Nuclear generation, and fractional generation of total electricity produced in several EU countries between 1995 and 2002, are reported by the World Nuclear Association. Electricity prices are reported by Eurostat in national currency units, in units of Euro/MWh and in Purchasing Power Standard (PPS) units per MWh. PPS units represent Euro Figures normalized for the different purchasing power of various EU countries, depending on a standard basket of products defined by Eurostat.

Nuclear Generation Share vs. Electricity Prices in EU Countries in 1999

1999 PPS/100 KWh

Country	1999 Percent Nuclear Share of Total Electricity Generation	Medium Industrial Customers 1.25 GWh, 500 KW, 2,500 h 1999 PPS/100 KWh	Large Industrial Custor 10 GWh, 2,500 KW, 4,0 1999 PPS/100 KWh
Italy	0	11.8	9.4
Portugal	0	10.8	9.6
Netherland	4	7.4	5.8
United Kingdom	28.9	6.6	5.5
Spain	31	8.8	7.6
Germany	31.2	9.1	7.5
Finland	33	4.5	3.9
Sweden	46.8	3.8	2.7
Belgium	57.7	9	7
France	75	6.4	5.5

Table 3

The national electricity price data in 1999 for one class of residential and two classes of industrial customers, expressed in PPS/100 KWh units, are shown in Table 3 above. The basic characteristics of the residential and industrial loads are defined in Table 3. The analyses were preformed in both Euro and PPS units, however the PPS based prices are considered more appropriate for inter-country comparisons and are shown below. Not all EU countries are represented here, either since they do not have any nuclear capacity installed or because their price data are not reported. The results below represent a (Large) sample of the EU countries in 1999, but are not comprehensive. Please also note that the fractional nuclear generation axis – the X-axis – is not drawn exactly to scale.

The impact of increased nuclear generation fraction in various EU Countries on the electricity prices to three classes of consumers are shown in Figures 3, 4, and 5, below.

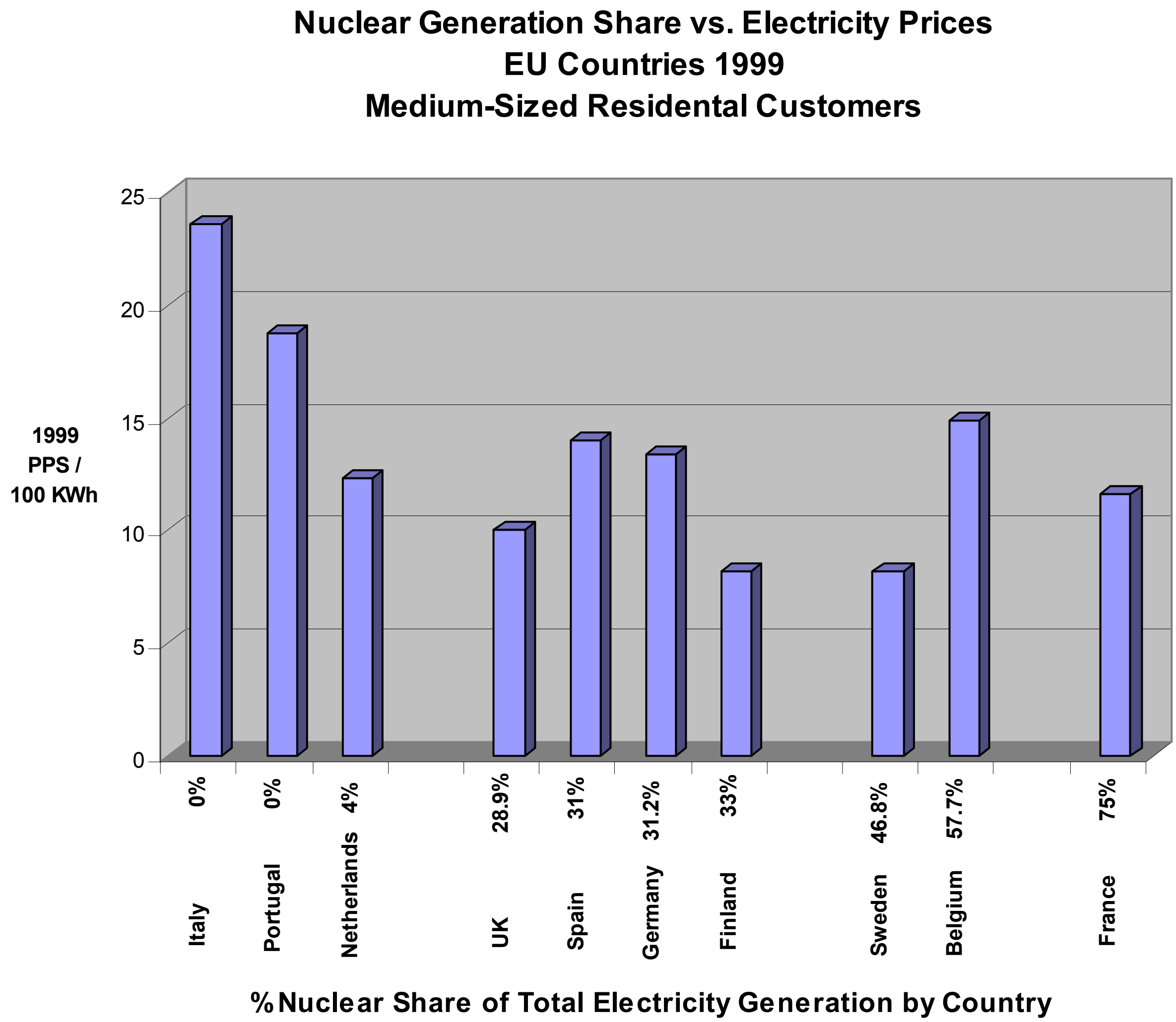
Nuclear Generation Share vs. Electricity Prices
EU Countries 1999
Medium-Sized Residental Customers
1999 PPS / 100 KWh
25
20
15
10
5
0
0% Italy
0% Portugal
4% Netherlands
28.9% UK
31% Spain
31.2% Germany
33% Finland
46.8% Sweden
57.7% Belgium
75% France
% Nuclear Share of Total Electricity Generation by Country

Figure 3

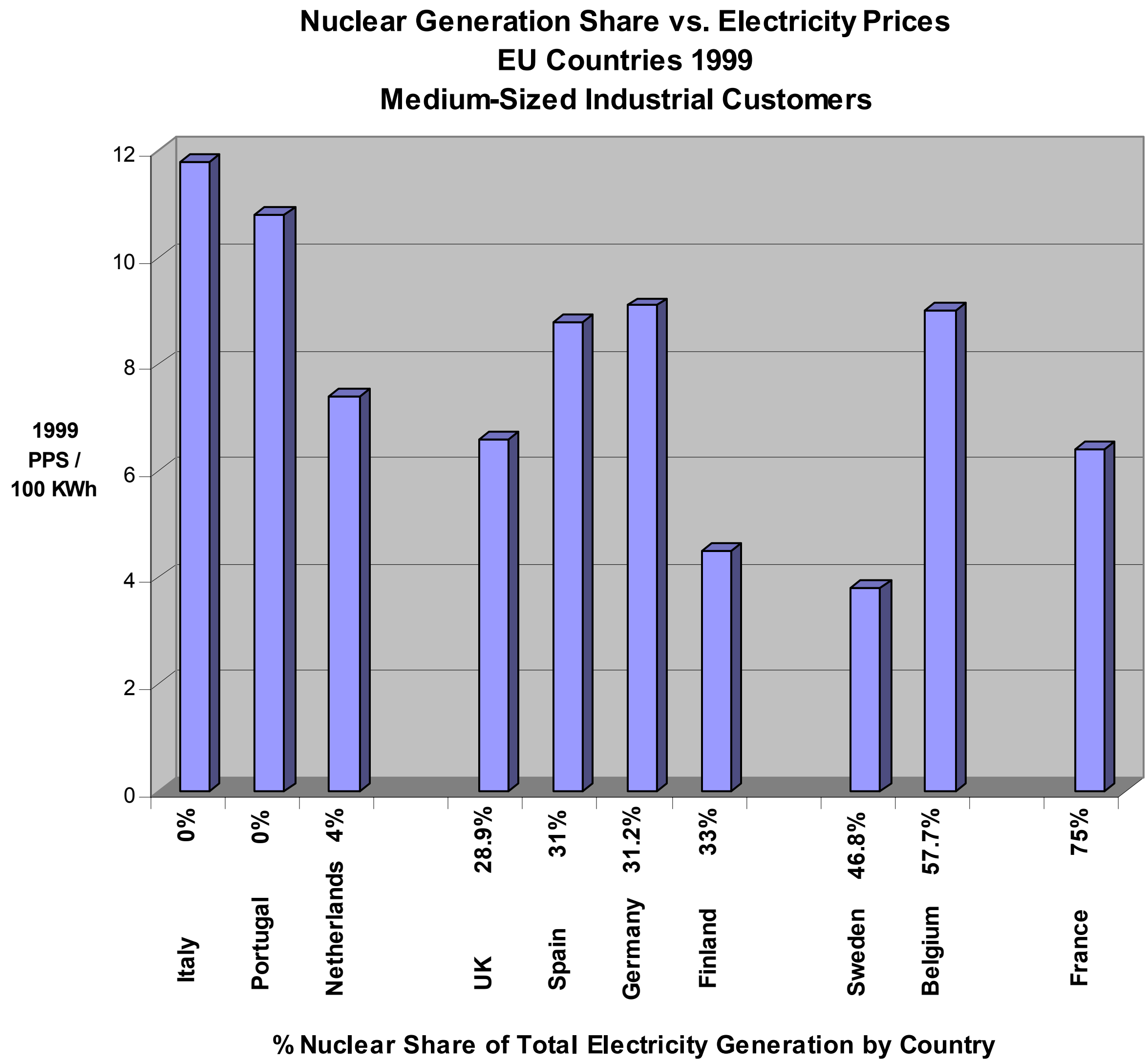
Nuclear Generation Share vs. Electricity Prices
EU Countries 1999
Medium-Sized Industrial Customers
1999
PPS /
100 KWh
0
2
4
6
8
10
12
0% Italy
0% Portugal
4% Netherlands
28.9% UK
31% Spain
31.2% Germany
33% Finland
46.8% Sweden
57.7% Belgium
75% France
% Nuclear Share of Total Electricity Generation by Country

Figure 4

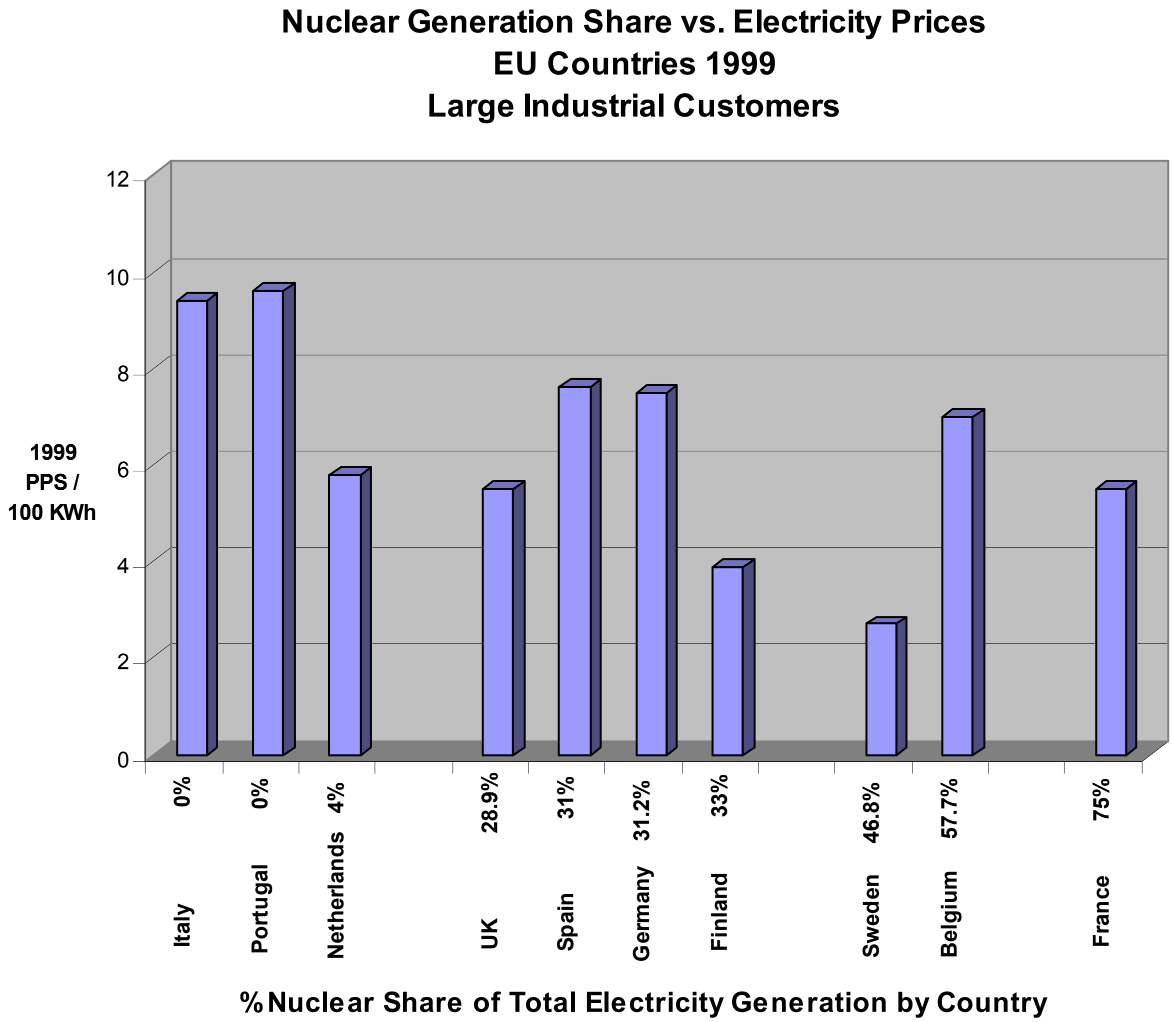

Figure 5

Figures 3, 4, and 5 represent a range of fractional nuclear generation within an EU country in 1999, ranging between zero (Italy, Portugal) and 75 percent (France). Inspection of the above three Figures indicates that as the nuclear generation fraction within an EU country increases, electricity prices decline. This is true for all six residential customer classes (only one medium-sized residential load is shown in Figure 3), and for the nine industrial customer classes (only two of which – a mid-sized and a large-sized load are shown in Figures 4, and 5, respectively). The general decline in electricity prices to various consumer classes is not uniform across the various EU countries shown here, due to different national practices in specifying prices (tariffs) to various consumer classes. The general trend, however, is evident. As nuclear generation fraction increases above zero across a large number of EU countries (in 1999), electricity prices generally decline, and the electricity tariffs to the various consumer classes are thus reduced, reflecting the lower averaged generation costs.

3. Impact of Regional Nuclear Fraction on Electricity Price Volatility

A preliminary analysis of the impacts of regional nuclear capacity fraction on regional electricity price volatility, was carried out by Brad Eccles and Elizabeth King of NEI, with consultation with Chaim Braun. Price volatility is defined as the standard deviation of a stream of electricity prices, extending over a period of time. An alternative definition of price volatility would be the standard deviation of prices divided by the mean of the prices time-series, and expressed in percentages, rather than in absolute price units ($/MWh). Electricity price volatility is a measure of the variability and instability in electricity prices, and it is caused by the fluctuations in the prices of energy fuels to the various generating units in a region. Higher volatility figures reflect higher uncertainties regarding the availability and prices of energy fuels. Nuclear plants with stable fuel and Operating and Maintenance (O&M) costs represent constant price (non-volatile) sources of power. Thus we would expect regions with high nuclear capacity to show less volatile electricity prices, and vice versa. Another reason for high volatility values is the emergence of periods of capacity shortages during times of peak demand. This drives up electricity prices (Create a price spike ten to twenty times higher than the normal price range), which increase the overall volatility of a stream of electricity prices extending over a long time period. Recall the MAIN-ECAR price spike of more than 7,000 $/MWh in and about June 30th, 1998, caused by shutdown of nuclear plants in MAIN and failed transmission interconnections in Wisconsin.

For the volatility analysis study, the NEI Analysts have calculated the average standard deviation in a stream of daily on-peak electricity prices extending over the 1997-2002 time period. The NEI analysts have made an adjustment for the effects of seasonality on electricity prices. They did not want to confuse seasonal variation in a region for variation in prices due to nuclear capacity. The results of the Preliminary analysis are shown in Figure 6 below. The basic data used in the analysis is reported in Table 1 above. A volatility definition of the standard deviation in electricity prices is used in Figure 6. However, similar results are also obtained when defining electricity prices volatility as the standard deviation, divided by the mean of the prices time series.

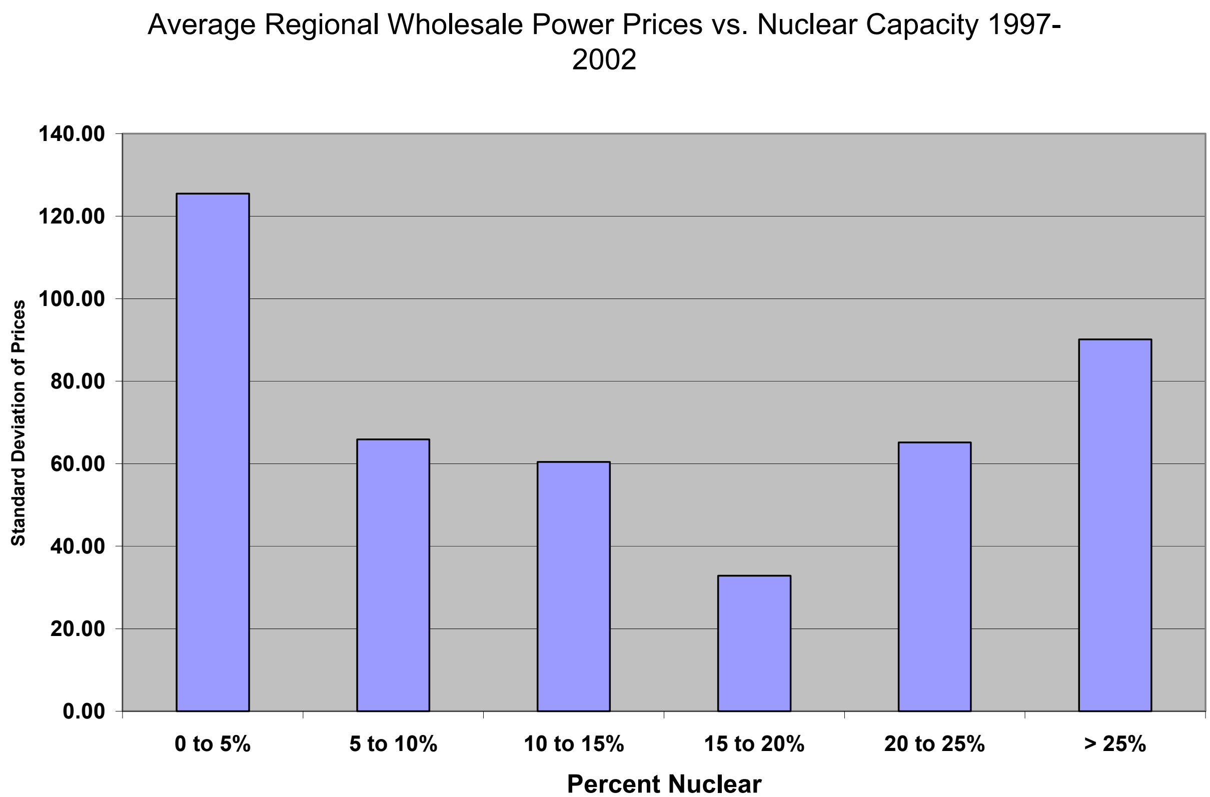

Figure 6

Inspection of Figure 6 indicates that there are high volatility values at both the high and the low ranges of the regional nuclear capacity fraction levels. We assume that the reason for this result is that volatility values are driven primarily by two factors, as mentioned above; Fluctuation in electricity fuel prices, and shortages in regional generating capacity during peak demand periods. We believe that the preliminary results shown in Figure 6 reflect a superposition of these two trends. At the zero to 20 percent nuclear capacity fraction range, the increasing impacts of the stable nuclear prices predominate. This effect is bolstered by the specifically high volatility values in California and the East Central region of the country (ECAR), representing episodes of capacity shortages in those regions that have created price spike periods. The overall result still implies that as nuclear capacity fraction increases price volatility decreases. This result partially bolstered by the price volatility – nuclear capacity fraction regression analysis over the entire range of regional nuclear capacity fractions shown in Figure 7 below, and the related statistical analysis reported in Table 4. There exists a downward trend of price volatility with increasing nuclear fraction but it cannot be declared statistically different from zero at the 95% confidence level. However it is significant at a 90% confidence level. The limited statistical validity is caused by the high volatility values found for some high nuclear capacity fraction regions, as indicated in Figure 7.

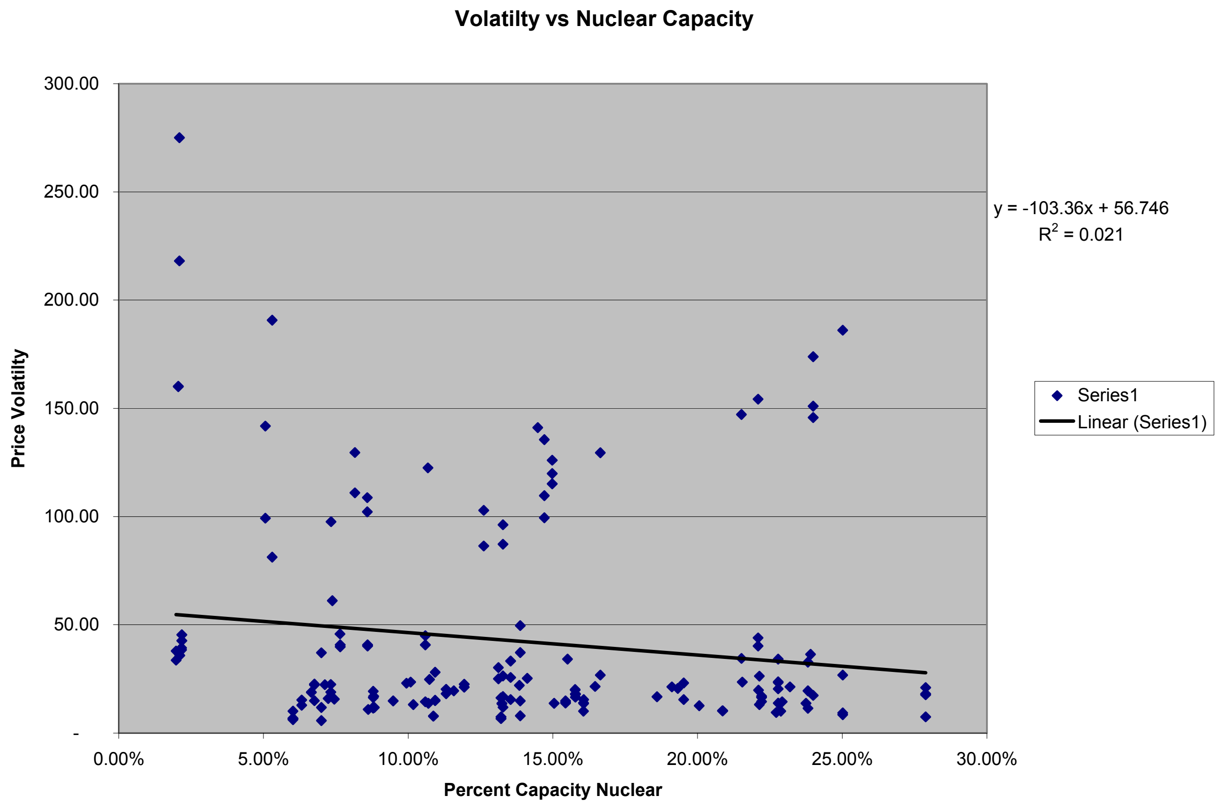

Figure 7

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.14
R Square	0.02
Adjusted R Square	0.02
Standard Error	48.70
Observations	169.00

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1.00	8,484.59	8,484.59	3.58	0.06

Residual	167.00	396,066.80	2,371.66
Total	168.00	404,551.39	

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	56.75	8.40	6.76	0.00	40.17	73.32
Average of Nuclear Capacity	(103.36)	54.65	(1.89)	0.06	(211.24)	4.53

Table 4

At the Higher nuclear capacity range (20-25 percent or more), the specific regional impacts of overall generating capacity shortages predominate. The increases in volatility at the 20-25 percent nuclear capacity range, as seen in Table 1, are driven by the MAIN price spike episode and by TVA which is not an unregulated region and is not subjected to market prices. The high volatility value above the 25 percent nuclear capacity fraction is solely determined by the MAIN price spike episode.

We believe that more analysis is required here to break apart the effects of price fluctuation and capacity shortages on volatility. This will include more refined data segmentation between regulated and non-regulated regions of the country, and time segmentation of the electricity price streams to exclude the episodes of regional capacity shortages and price spikes. This may also include volatility representation as electricity prices standard deviation, or as standard deviation divided by the mean. The analysis might be extended to look at regional nuclear generation fractions in addition to nuclear capacity fractions. The NEI analysts have also reviewed regional volatility values as function of gas-fired capacity fractions since gas fired plants are usually at the margin in many regions and do determine wholesale electricity prices in deregulated (market based) regions. The early conclusion from that review is that gas fuel capacity and price uncertainty are not major source of volatility relative to capacity shortage constraints. This issue might be revisited once better data segmentation is achieved.